

## AN ELECTROPHORETIC DISPLAY

## AND A METHOD OF DRIVING SAID DISPLAY

## BACKGROUND OF THE INVENTION

## 1. Field of the Invention

5 The present invention relates to an electrophoretic display and a  
6 method of driving said display, and more specifically to a method of selectively  
7 driving an electrophoretic display in a reflective mode or a direct-viewing  
8 display mode.

## 9 2. Description of Related Art

10 E-books have been developed recently, and many people prefer e-  
11 books to traditional books. An e-book uses a plane display screen to display  
12 digitally generated text so a person can read the e-book. The e-book has lots of  
13 advantages over conventional books, but the e-book has not been universally  
14 accepted. One reason the e-book has not been universally accepted is power-  
15 consumption. The plane display screen needs power to display text. When the  
16 power is turned off, the text disappears from the screen. Furthermore, a person  
17 must learn how to use the e-book. A method of conserving power while  
18 extending the persistence of the text on the screen is needed.

19 The power-consumption problem has been solved, and most people  
20 already know how to read an e-book, PDA, etc. The power-consumption  
21 problem was solved with the development of e-paper. E-paper is a reflective  
22 electrophoretic display material.

23 A company named E Ink developed a specific display material for the  
24 reflective electrophoretic display with embedded electronic ink. The electronic

1 ink's principal components are millions of tiny microcapsules, about the  
2 diameter of a human hair. With reference to Fig. 17A, each microcapsule (70)  
3 comprises multiple positively charged white particles (71) and multiple  
4 negatively charged black particles (72) suspended in a clear fluid (73). The  
5 microcapsule (70) has a top (not numbered) and a bottom (not numbered).  
6 When a voltage is applied to a microcapsule (70) with a negative potential  
7 applied to the top of the microcapsule (70) and a positive potential applied to  
8 the bottom of the microcapsule (70), the positively charged white particles (71)  
9 move to the top of the microcapsule (70), and the negatively charged black  
10 particles (72) move to the bottom of the microcapsule (70). The positively  
11 charged white particles (71) at the top are visible to a person and block the  
12 negatively charged black particles (72). That is, the top of the microcapsule (70)  
13 appears white, and the negatively charged black particles (72) are hidden. With  
14 reference to Fig. 17B, reversing the polarity of the voltage applied to the  
15 microcapsule (70) causes the negatively charged black particles (72) to move to  
16 the top of the microcapsule (70) and the positively charged white particles (71)  
17 to move to the bottom and make the microcapsule (70) appear dark. The E Ink  
18 claims that their e-paper can be read under direct sunlight and has advantages  
19 of high contrast, low power, wide field of vision, etc.

20 The Xerox company has also proposed a display principle similar to E  
21 Ink's. With reference to Fig. 18A, multiple rollers (81) are mounted on a single  
22 electrode plate (80). Each roller (81) has a black hemisphere (not numbered)  
23 and a white hemisphere (not numbered). The black hemisphere has a positive  
24 electric charge (+), and the white hemisphere has a negative electric charge (-).

1 When a negative electric potential is applied to the electrode plate (81), the  
2 black hemispheres of the rollers (81) face the electrode plate (80). On the other  
3 hand, when a positive electric potential is applied to the electrode plate (80),  
4 the white hemispheres of the rollers (81) face the electrode plate (80), as shown  
5 in Fig. 18B.

6 With reference to Fig. 19, the IBM company has developed an  
7 electrophoretic display also composed of two electrode plates (91, 92), a  
8 colored fluid (90) between the two electrode plates (91, 92) and multiple  
9 colored charged particles (93) suspended in the colored fluid (90). The  
10 operation of the electrophoretic display is similar to the forgoing descriptions  
11 and is not further described.

12 The examples of electrophoretic displays described have the following  
13 common features.

- 14 1. All the displays are reflective and display text by reflecting light in  
15 the environment.
- 16 2. Low power.
- 17 3. High contrast.
- 18 4. Clear image.

19 The forgoing features of e-paper are advantages, but the e-paper display cannot  
20 display clear text or images when the reflective display is used in an  
21 environment with weak light.

22 The present invention provides an electrophoretic display that has  
23 reflective or direct-viewing display mode to mitigate or obviate the  
24 aforementioned problems of the conventional methods.

1      SUMMARY OF THE INVENTION

2           An objective of the present invention is to provide an electrophoretic  
3        display that can selectively be a reflective display, a direct-viewing display or a  
4        combination reflective and direct-viewing display.

5           Other objectives, advantages and novel features of the invention will  
6        become more apparent from the following detailed description when taken in  
7        conjunction with the accompanying drawings.

8      BRIEF DESCRIPTION OF THE DRAWINGS

9           Fig. 1 is a side plan view in partial section of a first embodiment of an  
10        electrophoretic display pixel in accordance with the present invention;

11           Figs. 2 is a top plan view of a first embodiment of transparent  
12        electrodes of the electrophoretic display in accordance with the present  
13        invention;

14           Fig. 3 is a top plan view of a second embodiment of the transparent  
15        electrodes of the electrophoretic display in accordance with the present  
16        invention;

17           Fig. 4 is a top plan view of a third embodiment of the transparent  
18        electrodes of the electrophoretic display in accordance with the present  
19        invention;

20           Fig. 5 is a side plan view of a first embodiment of a colored particle for  
21        the electrophoretic display in accordance with the present invention;

22           Fig. 6 is a side plan view of a second embodiment of the colored  
23        particle for the electrophoretic display in accordance with the present invention;

24           Fig. 7 is an operational side plan view in partial section of the

1       electrophoretic display in Fig. 1 displaying a single black color;

2           Fig. 8 is an operational side plan view in partial section of the

3       electrophoretic display in Fig. 1 displaying a single white color;

4           Fig. 9 is an operational side plan view in partial section of the

5       electrophoretic display in Fig. 1 displaying light and black colors;

6           Fig. 10 is a side plan view in partial section of the electrophoretic

7       display in Fig. 1 with a backlit module in accordance with the present invention;

8           Fig. 11 is a side plan view in partial section in partial section of a

9       second embodiment of the electrophoretic display in accordance with the

10      present invention;

11          Fig. 12 is an operational side plan view in partial section of the second

12      embodiment of the electrophoretic display in Fig. 11;

13          Fig. 13 is a side plan view in partial section of a third embodiment of

14      the electrophoretic display in accordance with the present invention;

15          Fig. 14 is a top plan view of a fourth embodiment of the transparent

16      electrodes with a reflective layer in accordance with the present invention;

17          Fig. 15 is an operational side plan view of the electrophoretic display in

18      Fig. 13;

19          Fig. 16A is a cross sectional side plan view of the reflective layer of the

20      electrophoretic display in accordance with the present invention;

21          Fig. 16B is a side plan view of a fifth embodiment of the transparent

22      electrodes with a reflective layer in accordance with the present invention;

23          Fig. 16C is a top plan view of a sixth embodiment of the transparent

24      electrodes with the reflective layer in accordance with the present invention;

1           Fig. 16D is a top plan view of a seventh embodiment of the transparent  
2   electrodes with the reflective layer in accordance with the present invention;

3           Fig. 17A is a side plan view of a first conventional electrophoretic  
4   display in accordance with the prior art;

5           Fig. 17B an operational view of the first conventional electrophoretic  
6   display of Fig. 17A;

7           Fig. 18A is a side plan view of a second conventional electrophoretic  
8   display in accordance with the prior art;

9           Fig. 18B is an operational view of the second conventional  
10   electrophoretic display of Fig. 18A; and

11           Fig. 19 is a side plan view of a third conventional electrophoretic  
12   display in accordance with the prior art.

13           DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

14           An electrophoretic display (EPD) in accordance with the present  
15   invention has a reflective and direct-viewing display mode or a direct-viewing  
16   display mode. The EPD has multiple positively and/or negatively charged  
17   colored particles, two substrates each having multiple electrodes, wherein  
18   reflective and transmissive areas could be all defined on one of the two  
19   substrates or respectively on the two substrates. When applying opposite  
20   polarity of the voltage to at least two electrodes on the substrates, the charged  
21   colored particles are moved to the reflective areas or transmissive areas. That is,  
22   the charged color particles on the reflective areas or transmissive areas can be  
23   controlled whether the front light is reflected by the reflective area or not, or  
24   whether the backlight passes through the EPD or not. Therefore, by controlling

1 the applied polarity of voltage, the EPD can be operated in a reflective display  
2 mode if the surrounding light is sufficient, or in a direct-viewing display mode  
3 when the surrounding is dim.

4 With reference to Fig. 1, each pixel of a first embodiment of the EPD in  
5 accordance with the present invention includes a first substrate (10), a second  
6 substrate (20), colored charged particles (31, 32) and fluid (33). The fluid (33)  
7 between the first and second substrates (10, 20) can be transparent or colored.  
8 The colored charged particles has dark and white colored charged particles (31,  
9 32) that are suspended in the fluid (33).

10 The first substrate (10) can be made of a transparent material such as  
11 glass or plastic etc.. In this preferred embodiment, the first substrate (10) has an  
12 outer face (101) and an inner face (102). The outer face (101) to which the  
13 front light from the front light module (not shown) passes through is a front  
14 face of the EDP for displaying images or text etc.. The front light module can  
15 be mounted on the front face. A first transparent electrode (11) is printed on the  
16 inner face (102) and has at least one first transparent electrode layer (11). The  
17 first transparent electrode layer (11) can be defined as the reflective area by  
18 collecting enough dark or white colored particles (31, 32).

19 The second substrate (20) can be made of a transparent or opaque  
20 material such as glass, plastic and stainless steel etc.. In this preferred  
21 embodiment, the second substrate (20) is transparent and parallel with the first  
22 substrate (10). The second substrate (20) has an inner face (202) and an outer  
23 face (201) defined as a rear face of the EDP. The inner face (202) is faced to the  
24 inner face (102) of the first substrate (10). The second transparent electrode (21)

1 has at least two second transparent electrode layers (211, 212, 213). In this  
2 preferred embodiment, three second transparent electrode layers (211, 212, 213)  
3 are printed on inner face (202) of one pixel of the second substrate (20) and two  
4 transmissive areas each is defined between the two second transparent  
5 electrode layers (211, 212, 213).

6 To increase brightness of the EDP in the direct-viewing display mode,  
7 with further reference to Fig.10, a backlit module (40) is adapted to mount to  
8 the rear face (201) of the EPD. The backlight radiated from the backlit module  
9 (40) can pass through the transmissive areas to the front face (101). The backlit  
10 module (40) can be an EL (electro luminescent), PLED (polymeric light  
11 emitting diode) or OLED (organic light emitting diode).

12 With reference to Figs. 2 and 3, three second electrode layers (211, 212,  
13 213) of the first embodiment of the EDP are parallel with each other and each  
14 second electrode layer (211, 212, 213) can be formed as a long narrow strip  
15 shape or a substantially < shape. With reference to Fig. 4, one pixel of the  
16 second substrate (20) has two second electrode layers (211, 212), one is a  
17 rectangular frame and the other is a squire shape in the rectangular frame. The  
18 two second electrode layers (211, 212) are period arrangement. These examples  
19 are only one part of useful shapes for the second electrode layers.

20 The dark and white colored charged particles (31, 32) filled between  
21 the first and second substrates (10, 20) respectively have positive or negative  
22 charge. In the first preferred embodiment of Fig. 1, the EPD has positively  
23 charged black particles (31) and negatively charged white particles (32)  
24 between the first and second substrates (10, 20). With reference to Fig. 5, the

1 EPD also can use microcapsules (30). Each microcapsule (30) has a transparent  
2 capsule (not numbered) in which clear fluid (33) and colored charged particles  
3 (31, 32) are contained. With reference to Fig. 6, the EPD uses rollers (30').  
4 Each roller (30') is composed of a white hemisphere (31') and a dark  
5 hemisphere (32'). The whit hemisphere (31') possess a positive electric charge  
6 (+), and the black hemisphere (32') possess a negative electric charge (-).

7 The forgoing description discloses a basic structure of the EPD. The  
8 following means for driving the EDP is used to the forgoing EPD to make the  
9 EPD to have a reflective and/or a direct viewing display mode or a direct  
10 viewing display mode.

11 (1) Reflective display mode of the EPD:

12 With reference to Fig. 7, a negative potential voltage and a positive  
13 potential voltage are respectively applied to the first and second electrode  
14 layers (11, 211, 212, 213) of the EDP. The positively charged black particles  
15 (31) are moved and collected to the first electrode layer (11) and the negatively  
16 charged white particles (32) are moved and collected to the second electrode  
17 layers (11, 211, 212, 213). Therefore, the reflective area is established on the  
18 first substrate (10) by collecting these positively charged black particles. That is,  
19 the front face displays dark spot because the front light is not reflected by the  
20 black charged particles and the backlight is blocked not to pass through the first  
21 substrate (10).

22 With reference to Fig. 8, reserving the potentials of voltages applied to  
23 the first and second electrode layers (11, 121, 122, 123) causes the negatively  
24 charged white particles (32) to be moved and collected to the first electrode

1 layer (11) and the positively charged black particles (32) to be moved and  
2 collected to the second electrode layers (211, 212, 213). The front face displays  
3 light spot because the front light is reflected by the negatively charged white  
4 particles that is collected to the first electrode layer (11).

5 (2) Direct viewing display mode of the EPD:

6 With reference to Fig. 9, the means for driving the EPD is  
7 accomplished by applying a negative and a positive potential voltages to the  
8 second electrode layers (211, 212, 213). That is, the positive potential voltage is  
9 applied to the two second electrode layers (211, 213) and the negative potential  
10 voltage is applied to the one second electrode layer (212). All the white and  
11 black particles (31, 32) are connected to the three second electrode layers (211,  
12 212, 213). Each transmissive area is defined between two of the second  
13 electrode layers (211 to 213) so the backlight can pass through the second and  
14 first substrates. The EPD display light spots.

15 With reference to Fig. 11, a second embodiment of the EPD in  
16 accordance with the present invention is similar to the first embodiment. In the  
17 second embodiment, a first electrode (11) has three first electrode layers (111 to  
18 113) printed on an inner face (not numbered) of the first substrate (10). Each  
19 first electrode layers (111, 122, 113) is aligned with the corresponding second  
20 electrode layers (211 to 213). Therefore, one pixel of the EPD has three pairs of  
21 first and second electrode layers (111, 211) (112, 212) (113, 213).

22 The means for driving EPD further uses a positive potential voltage and  
23 a negative potential voltage to apply to one pair of the first and second  
24 electrode layers (112, 212). With reference to Fig. 12, when the first electrode

1 layer (112) is connected to the positive potential voltage and the second  
2 electrode layer (212) is connected to the negative potential voltage, the black  
3 and white particles (31, 32) are respectively collected to the pair of the first and  
4 second electrode layers (112, 212). The other two pairs of the first and second  
5 electrode layers (111, 211) (113, 213) do not collect any particles (31, 32) so  
6 more backlight can pass through the second substrate (20) to the first substrate  
7 (10). Therefore, the front face (101) is brighter than the first embodiment of the  
8 Fig. 10.

9 With reference to Fig. 13, a third embodiment of the EPD in  
10 accordance with the present invention is similar to the second embodiment of  
11 Fig. 11. The third embodiment of the EPD comprises a first substrate (10), a  
12 second substrate (20), three first electrode layers (111 to 113) formed on the  
13 first substrate (10), two second electrode layers (211, 212) formed on the  
14 second substrate (20), a reflective layer (51) formed on the second substrate (20)  
15 on which the second electrodes do not formed (as shown in Fig. 14), and  
16 multiple single colored (black) charged particles (31).

17 The two second electrode layers (211, 212) are parallelly formed on the  
18 second substrate (20). The first electrode layers (111 to 113) are not aligned  
19 with the second electrode layers (211, 212). The second electrode layers (211,  
20 212) are transparent so the second electrode layers (211, 212) are defined as  
21 transmissive areas of EPD. The reflective layer (51) is made of multiple films  
22 with high reflectance.

23 With reference to Fig. 13, when all black charged particles (31) are  
24 collected to the second substrate (20), the backlight can not pass the

1 transmissive areas and the front light is not reflected upward by the black  
2 charged particles (31). Therefore, the front face of the EPD displays dark spot.

3 With reference to Fig. 15, an electric filed is applied to the three first  
4 electrode layers (111 to 113) and the black charged particles (31) are collected  
5 on the first electrode layers (111 to 113). The front light passes through the first  
6 substrate between two of the first electrode layers (111 to 113) and then is  
7 reflected upward by the reflective layer (51). In addition, the backlight also  
8 passes through the second substrate (20) to the first substrate. Therefore, the  
9 front face (101) of the EPD displays bright spots.

10 To increase the brightness of the front face (101) the reflective layer  
11 (51) has an upper face (511). With reference to Fig. 16A, the upper face (511)  
12 can be processed to be diffusive or random wave shaped to provide a scattering  
13 capability. The upper face (511) can be a flat as a mirror. With reference to Fig.  
14 16B, the second electrode layers (211) and the reflective layer (51) are  
15 alternately formed on the second substrate (not shown). With reference to Fig.  
16 16C, each second electrode layer (211) is circle formed on the second substrate  
17 (not shown) and the reflective layer (51) is formed on the second substrate  
18 which is not covered by the second electrode layers (211). With reference to  
19 Fig. 16D, the three second electrode layers (211) are paralleled to each other on  
20 the second substrate and the reflective layer (51) is formed on the second  
21 substrate.

22 Based on the forgoing description, the present invention discloses an  
23 EPD having reflective and direct-viewing display modes by selectively  
24 controlling a driving means of the EPD. That is, the EPD can become reflective

1 display or a direct-viewing display. When the EPD in sunshine environment,  
2 the EPD has enough front light to display so the EPD uses the reflective display  
3 mode. On the other hand, when the EPD in light weak environment, the EPD  
4 can drive the backlight module to provide a backlight and uses the direct-  
5 viewing display mode. Therefore, the present invention can provide high  
6 quality of display information or image whether the light is enough or not.

7 Even though numerous characteristics and advantages of the present  
8 invention have been set forth in the foregoing description, together with details  
9 of the structure and function of the invention, the disclosure is illustrative only,  
10 and changes may be made in detail, especially in matters of shape, size, and  
11 arrangement of parts within the principles of the invention to the full extent  
12 indicated by the broad general meaning of the terms in which the appended  
13 claims are expressed.